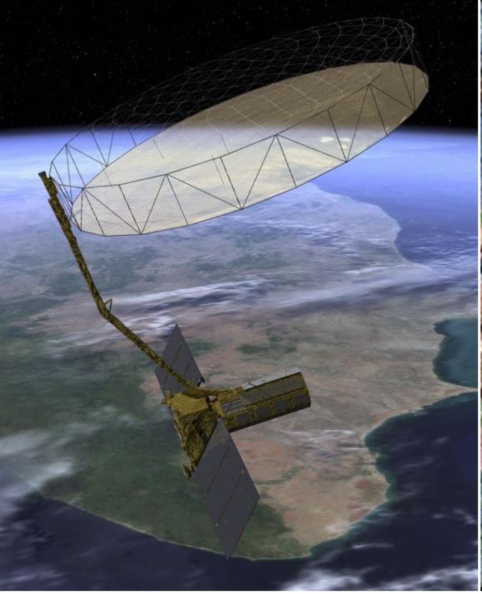
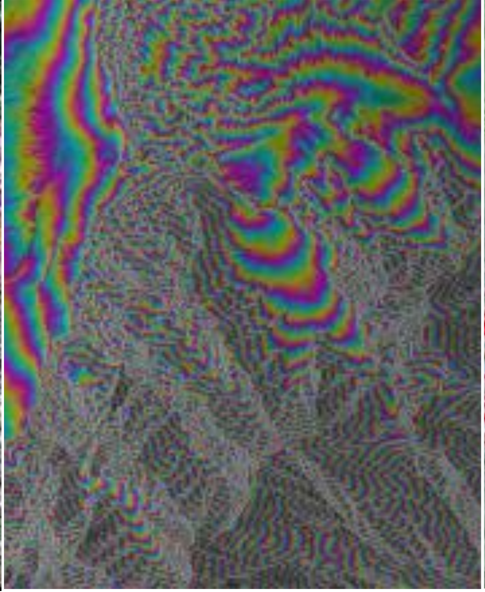





NASA-ISRO SAR Mission: Sensors and Potential Applications

Paul A Rosen, Scott Hensley, Scott Shaffer, Wendy Edelstein, Yunjin Kim, Dankai Liu, Pam Hoffman, Phil Barela, Peter Xaypraseuth
Jet Propulsion Laboratory, California Institute of Technology

Raj Kumar, Tapan Misra, Rakesh Bhan
ISRO Space Applications Centre

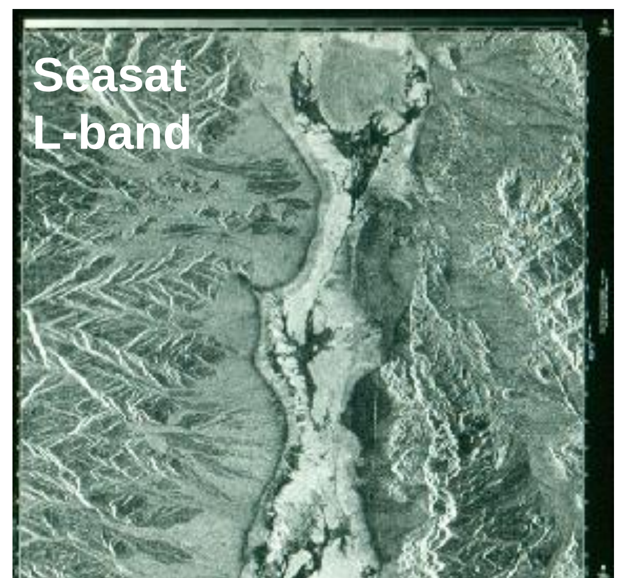
Raju Sagi
ISRO Satellite Centre

Asian Conference on Remote Sensing 2017
New Delhi, India
October 23, 2017

Jet Propulsion Laboratory
California Institute of Technology

Radar Remote Sensors

- **Altimeters**
  - height of a surface
- **Sounders/Profilers**
  - volume composition and structure
- **Scatterometers**
  - surface composition and roughness
- **Synthetic Aperture Radar (SAR)**
  - surface composition and roughness imagery
- **Polarimeters**
  - improves surface or volume structure information
- **Interferometers**
  - topography and topographic change



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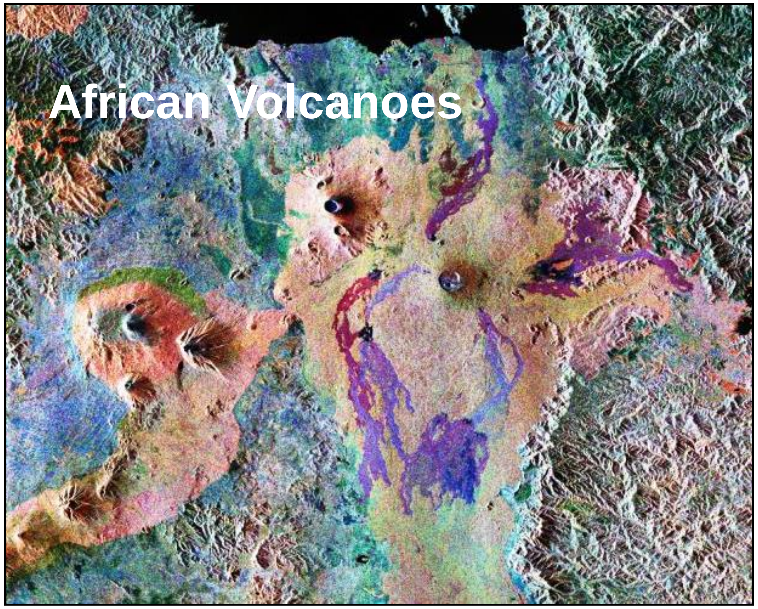

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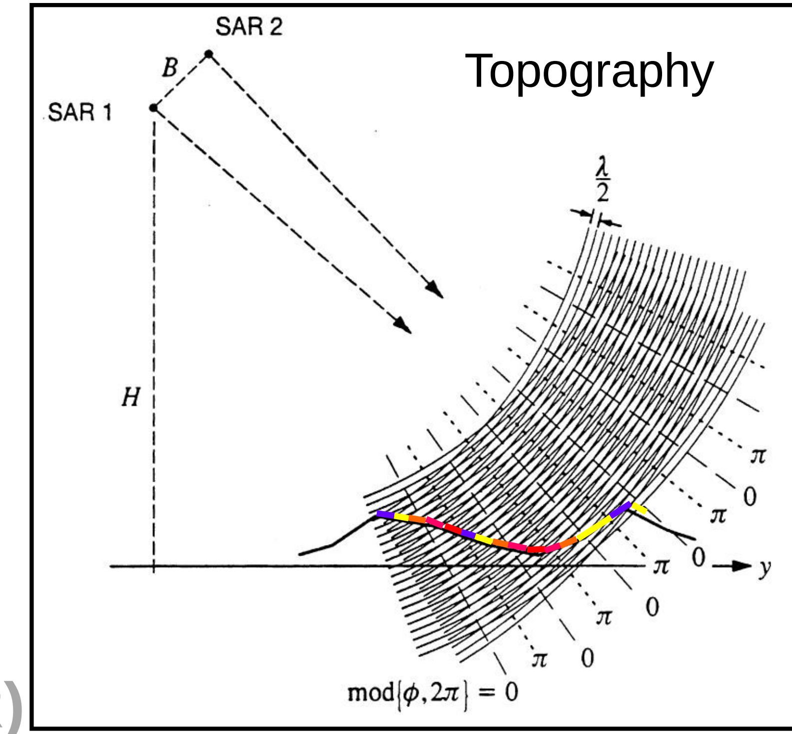
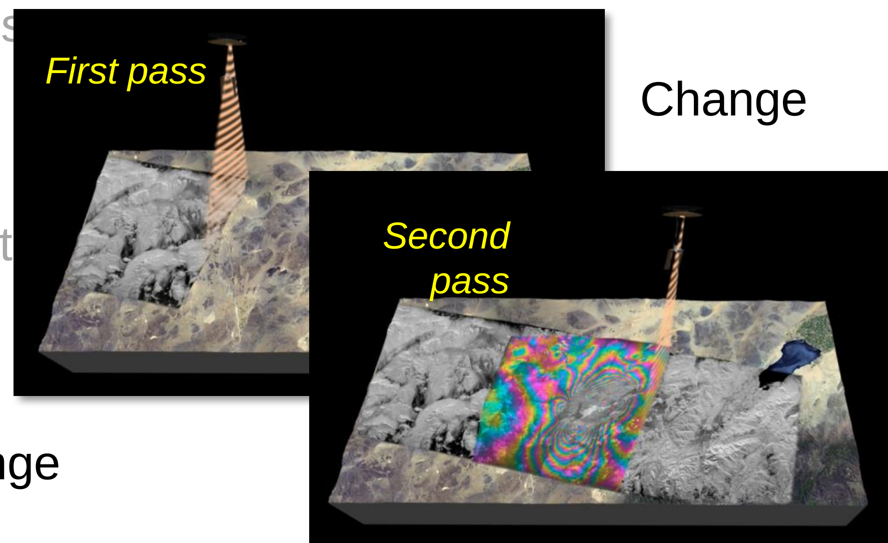




Change

SAR: beyond visible

- SAR at microwave wavelengths interact with the *geometric* and *electrical* properties of surfaces
- SAR observations allow us to experience the Earth in a fundamentally different light, day or night
- SAR at typical wavelengths can penetrate cloud cover

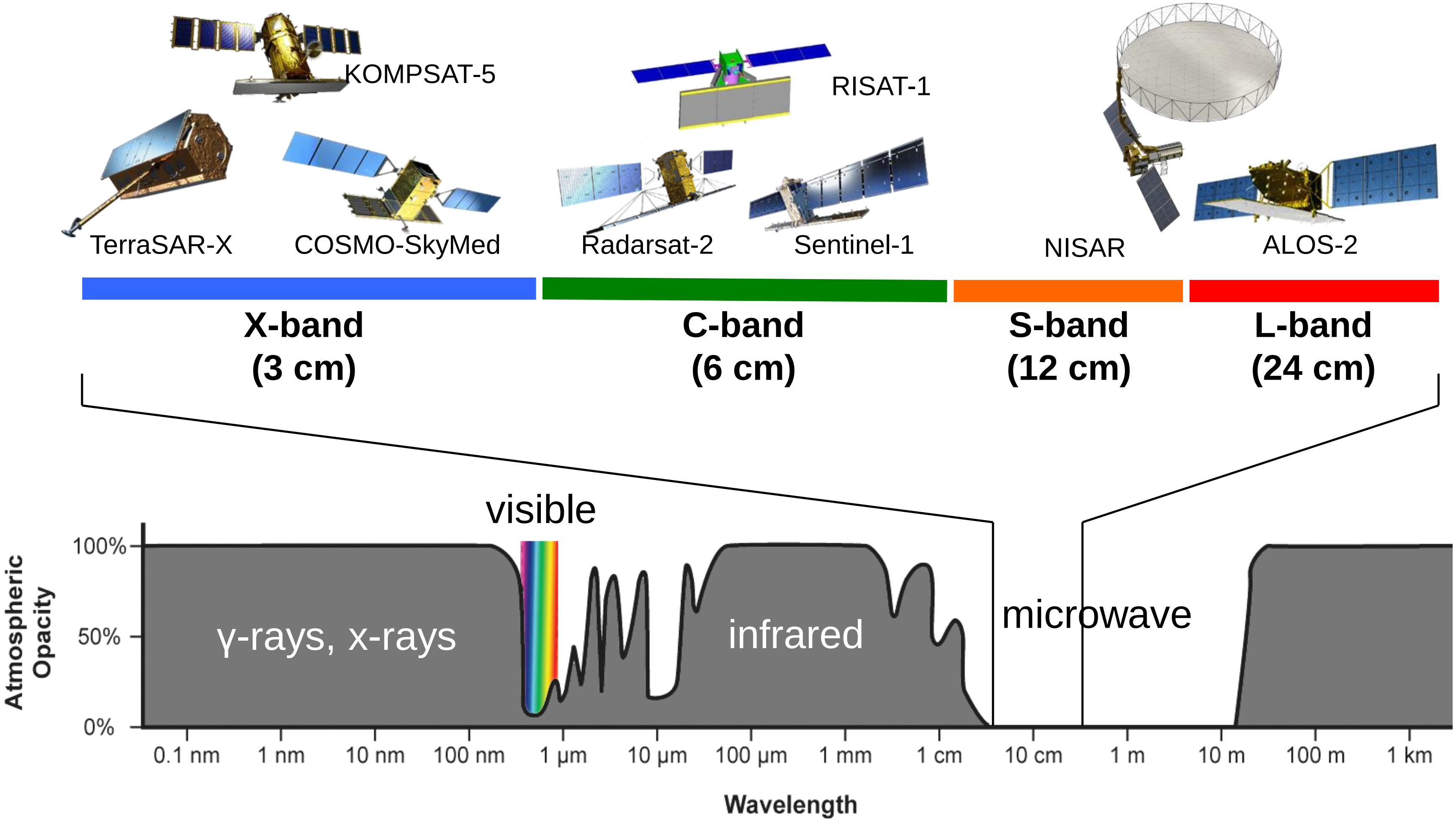
Optical

L-band (24 cm) SAR
Shuttle Imaging Radar-A

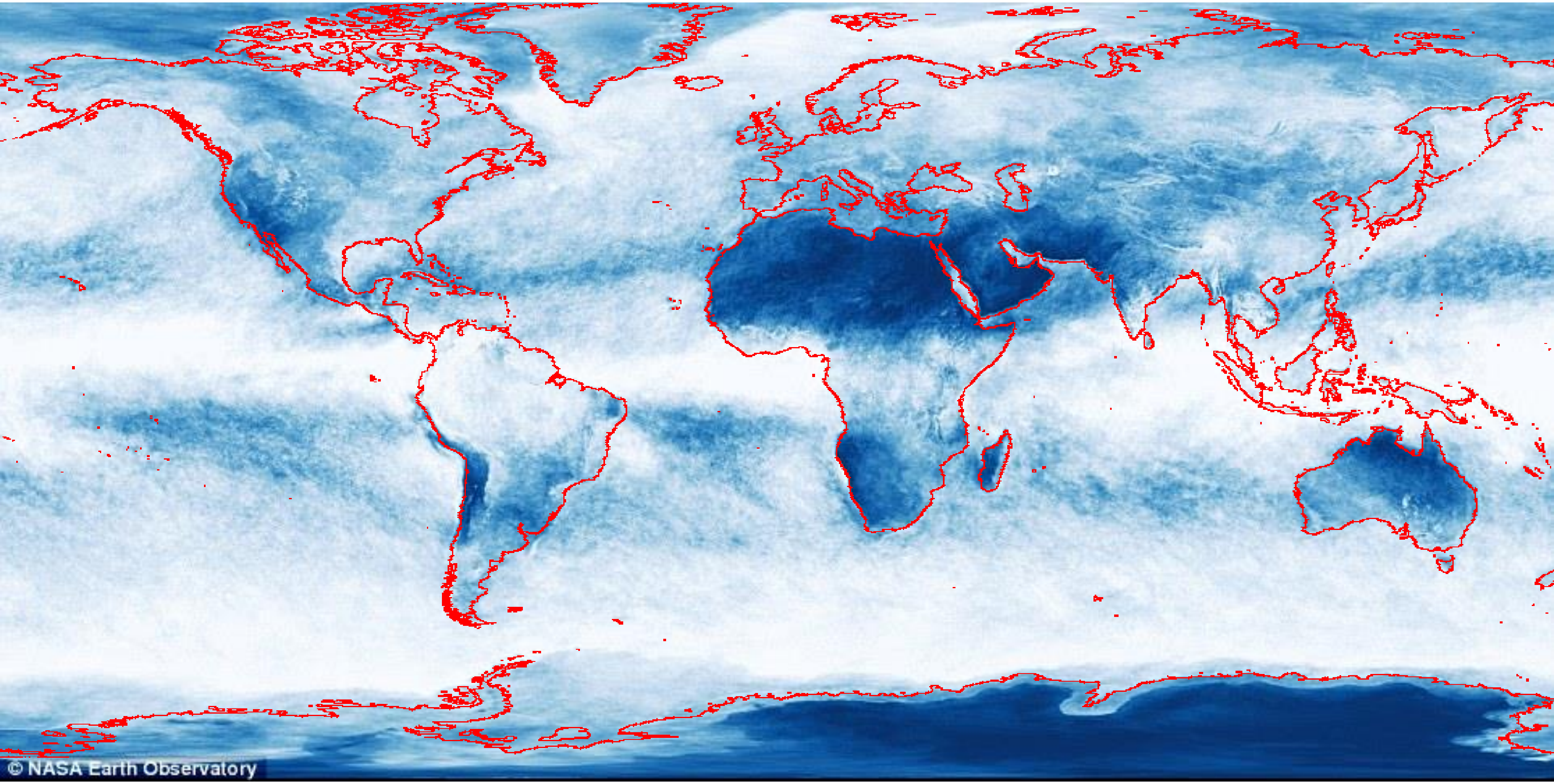
SAR for Broad Applications

Application	Benefit Through Regular SAR Monitoring of:
Global Food Security	- Soil moisture and crop growth at agricultural scale - Desertification at regional scales
Freshwater Availability	- Aquifer use/extent regionally - Water-body extent changes - Glaciers serving as water sources
Human Health	- Moisture and vegetation as proxy for disease and infestation vectors
Disaster Prediction & Hazard Response	- Regional building damage and change assessment after earthquakes - Earthen dams and levees prone to weakening - Volcanoes, floods, fires, landslides, oil spills
Climate Risks and Adaptation	- Ice sheet/sea-ice dynamics; response to climate change - Coastal erosion & processes and shoreline migration
Urban Management and Planning	- Urban growth through coherent change detection - Building deformation and urban subsidence
Human-activity Based Climate Change	- Deforestation's influence on carbon flux - Oil and gas reservoirs

Atmospheric Windows & Current SAR Missions

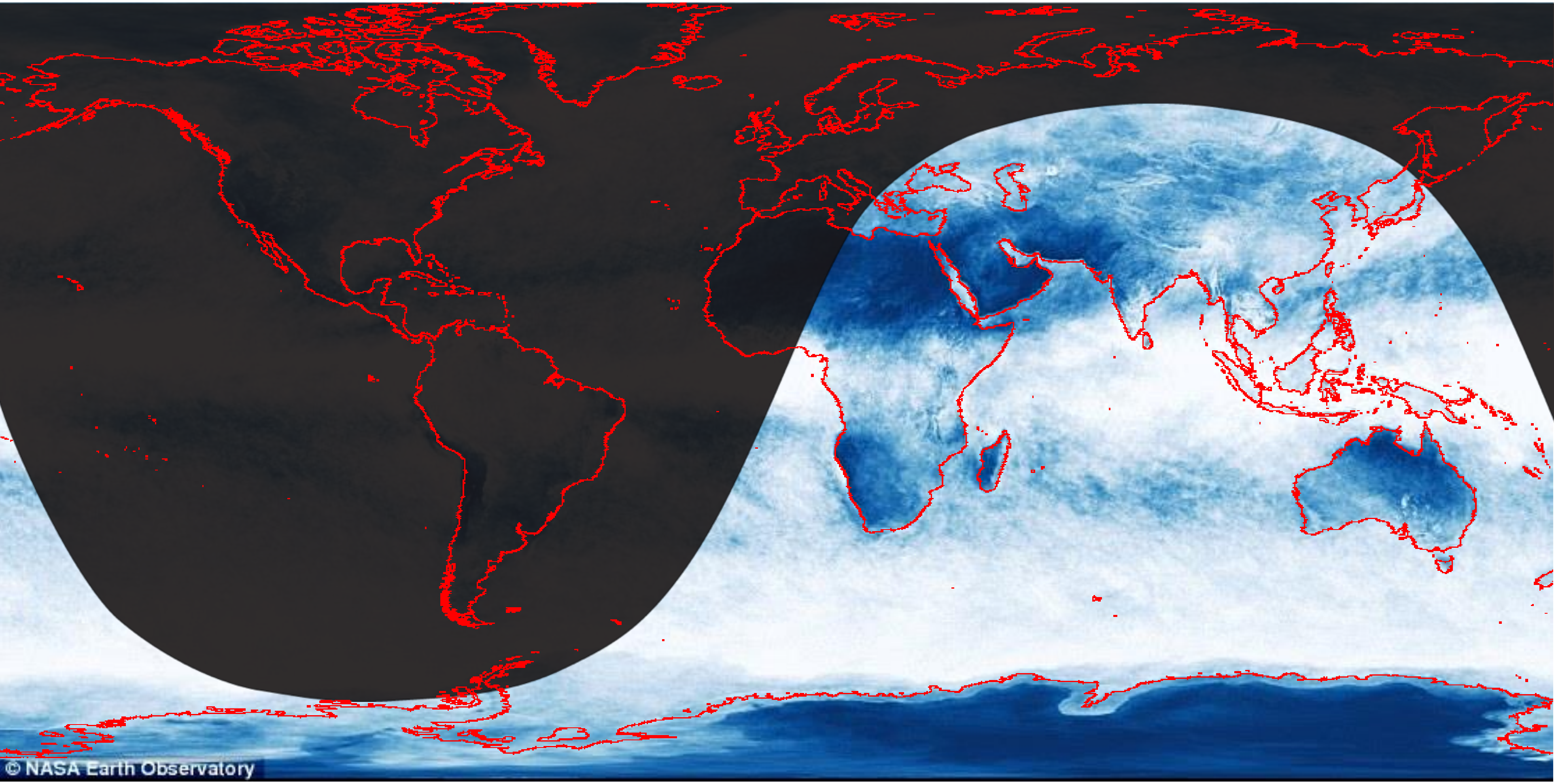


Earth is Mostly Cloudy



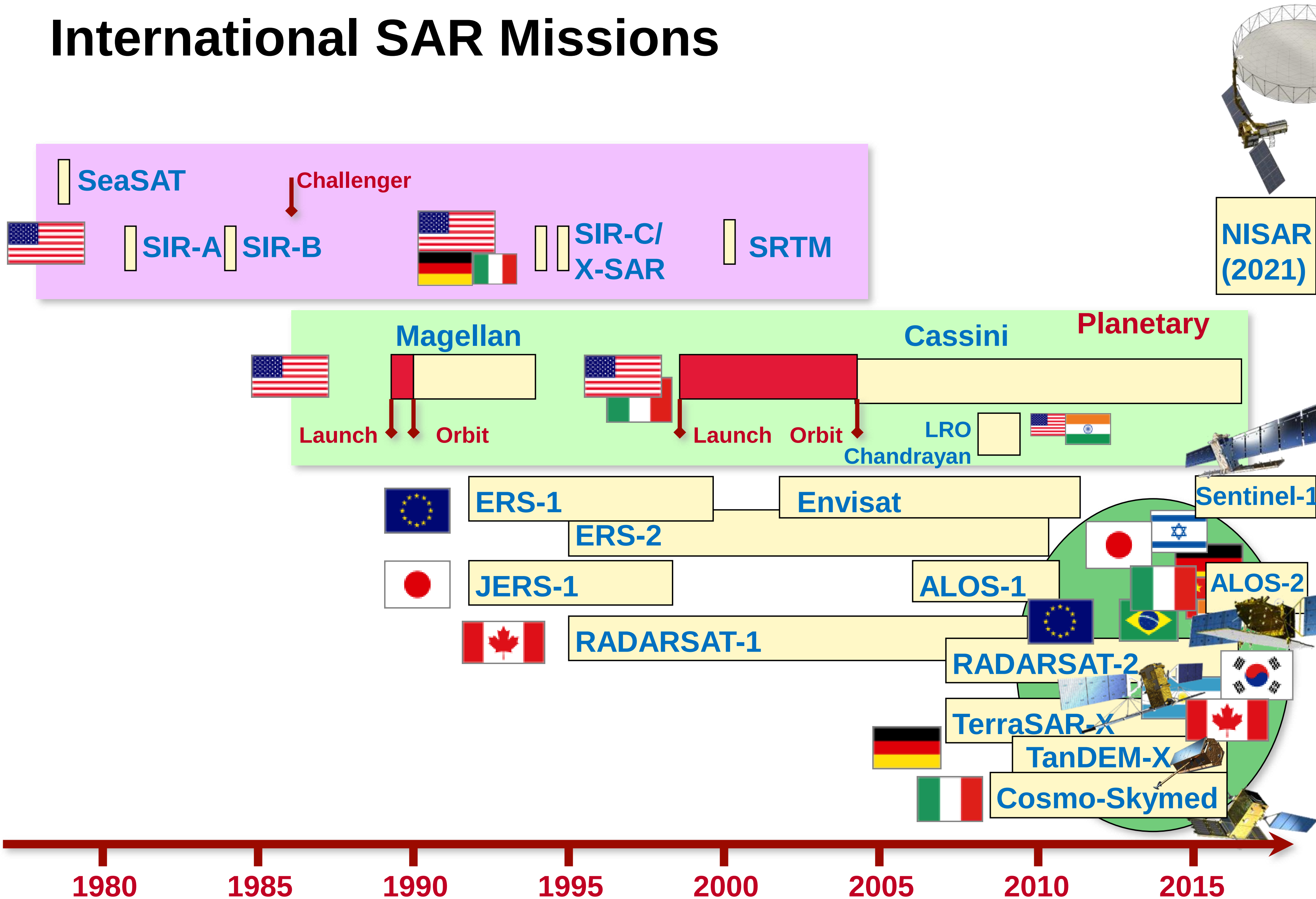
Average cloudiness over Earth in April 2015 seen from Aqua Satellite.
At any given time, around 70% of the Earth is covered by clouds.

And Half Dark



At any given time, 50% of the earth is dark.

International SAR Missions



NASA-ISRO Synthetic Aperture Radar (NISAR) Mission Objectives

Key Scientific Objectives:

- Understand the response of ice sheets to climate change and the interaction of sea ice and climate
- Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems
- Determine the likelihood of earthquakes, volcanic eruptions, and landslides

Key Applications Objectives:

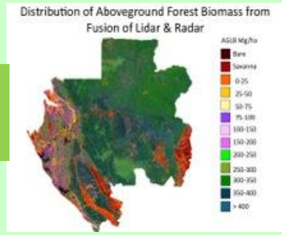
- Understand societal impacts of dynamics of groundwater, hydrocarbon, and sequestered CO_2 reservoirs
- Provide agricultural monitoring capability in support of food security objectives
- Apply NISAR's unique data set to explore the potentials for urgent response and hazard mitigation

To be accomplished in partnership with the Indian Space Research Organisation (ISRO) through the joint development and operation of a space-borne, dual-frequency, polarimetric, synthetic aperture radar (SAR) satellite mission with repeat-pass interferometry capability

NISAR Mission Concept Overview

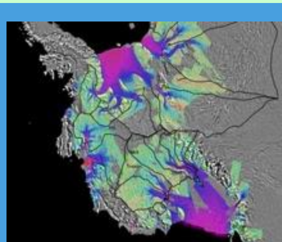
Mission Science

Ecosystem Structure



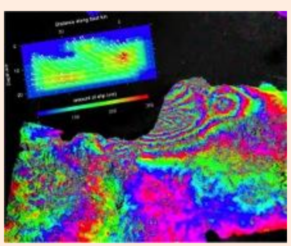
Biomass disturbance; effects of changing climate on habitats and CO_2

Cryosphere



Ice velocity, thickness; response of ice sheets to climate change and sea level rise

Solid Earth

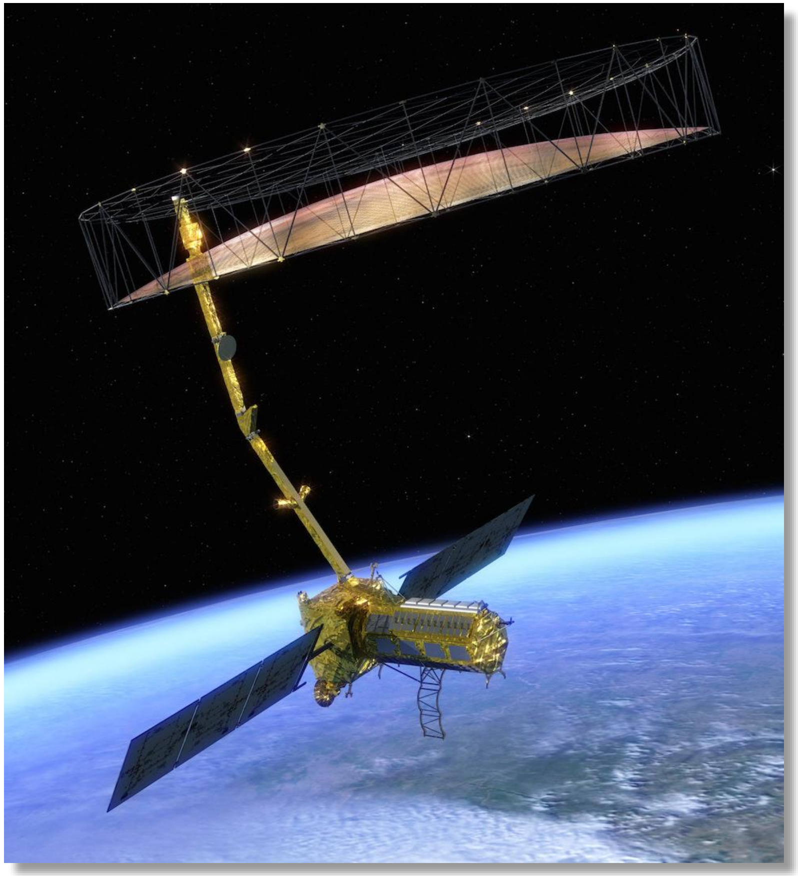


Surface deformation; geo-hazards; water resource management

- Major partnership between US National Aeronautics and Space Administration (NASA) and Indian Space Research Organisation (ISRO)
- Baseline launch date: No earlier than December 2020
- Dual frequency L- and S-band Synthetic Aperture Radar (SAR)
  - L-band SAR from NASA and S-band SAR from ISRO
- NASA 3.5 Gbps Ka-band telecom system to polar ground stations (> 26 Tbits/day downlink capability)
- Spacecraft: ISRO I3K with 2.8 Gbps telecom system
- Launch vehicle: ISRO Geosynchronous Satellite Launch Vehicle (GSLV) Mark-II (4-m fairing)
- 3 years science operations (5+ years consumables)
- All science data (L- and S-band) will be made available free and open, consistent with the long-standing NASA Earth Science open data policy

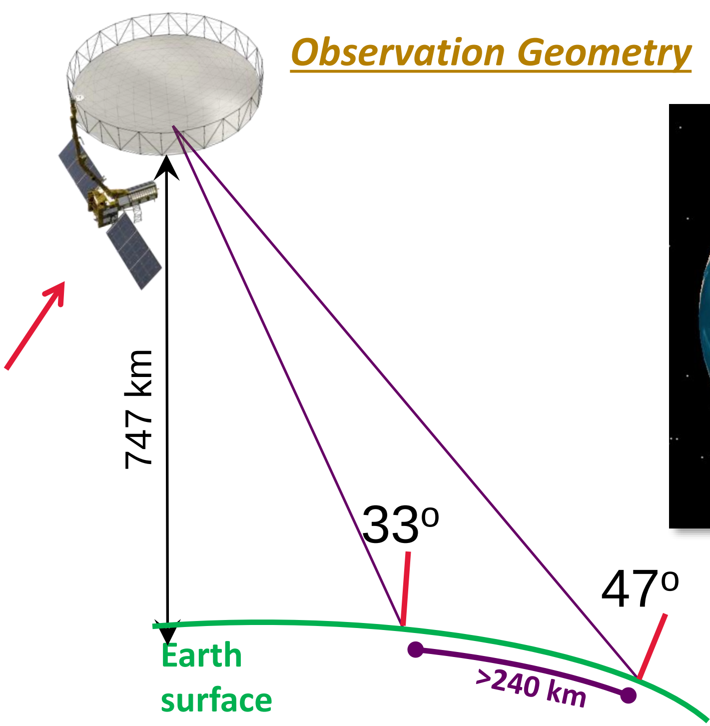
NISAR
NASA-ISRO SAR Mission

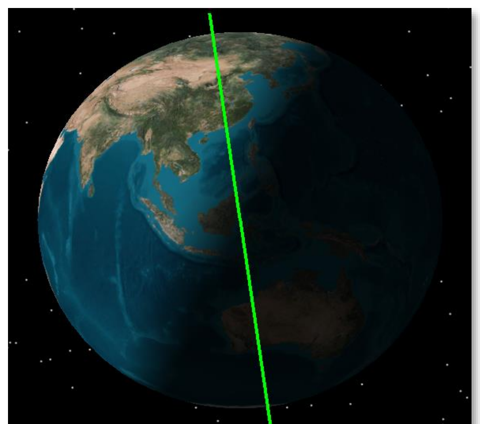
NISAR Characteristic:	Enables:
L-band (24 cm wavelength)	*Low temporal decorrelation and foliage penetration*
S-band (12 cm wavelength)	*Sensitivity to light vegetation*
SweepSAR technique with Imaging Swath > 240 km	*Global data collection*
Polarimetry (Single/Dual/Quad)	*Surface characterization and biomass estimation*
12-day exact repeat	*Rapid Sampling*
3 – 10 meters mode-dependent SAR resolution	*Small-scale observations*
Pointing control < 273 arcseconds	*Deformation interferometry*
Orbit control < 500 meters	*Deformation interferometry*
L/S-band > 50/10% observation duty cycle	*Complete land/ice coverage*
Left/Right pointing capability	*Polar coverage, north and south*

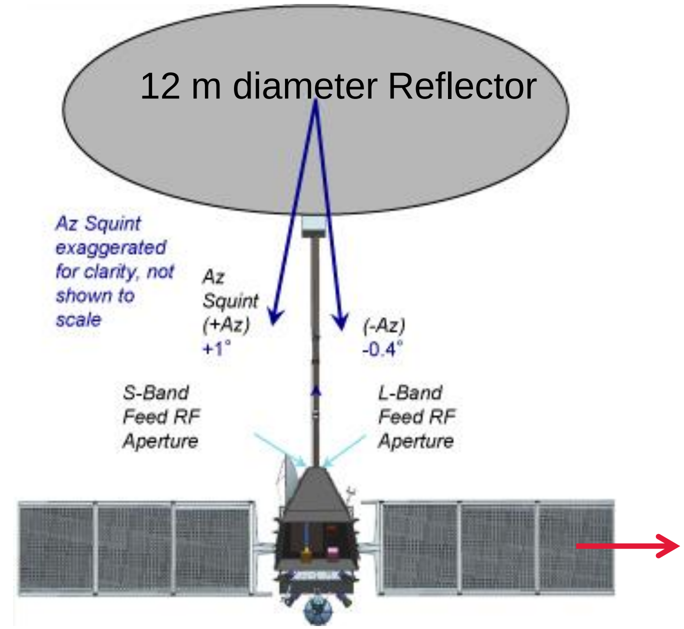


NISAR Imaging and Orbit Geometry

- Wide swath in all modes
- Data acquired ascending and descending
- Left/right pointing capability

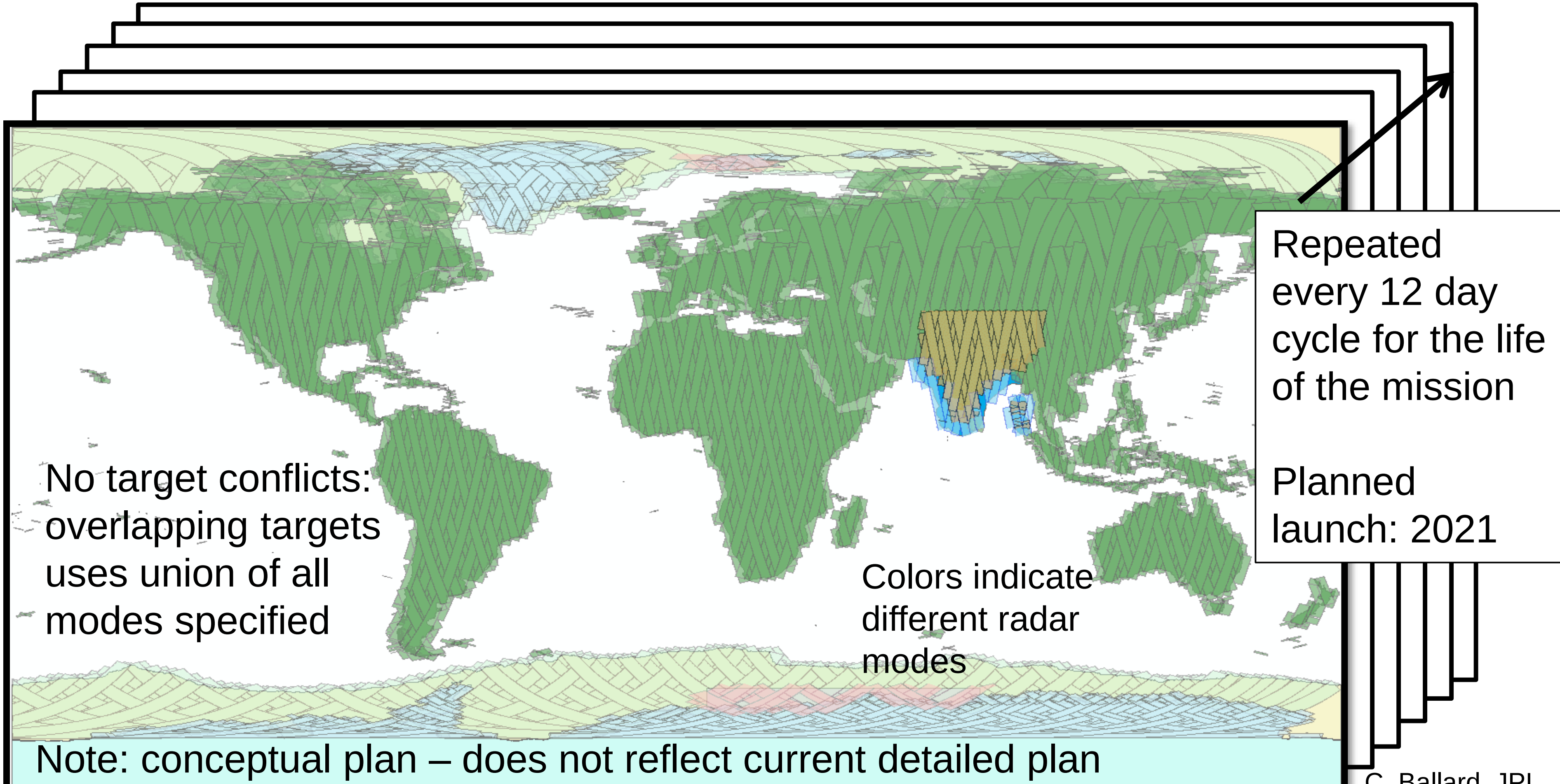






6 AM / 6 PM Orbit
98.5° inclination
Arctic Polar Hole: 87.5R/77.5L
Antarctic Polar Hole: 77.5R/87.5L

NISAR Systematic Observations
L-band globally – S-band selectively



C. Ballard, JPL

Persistent updated measurements of Earth

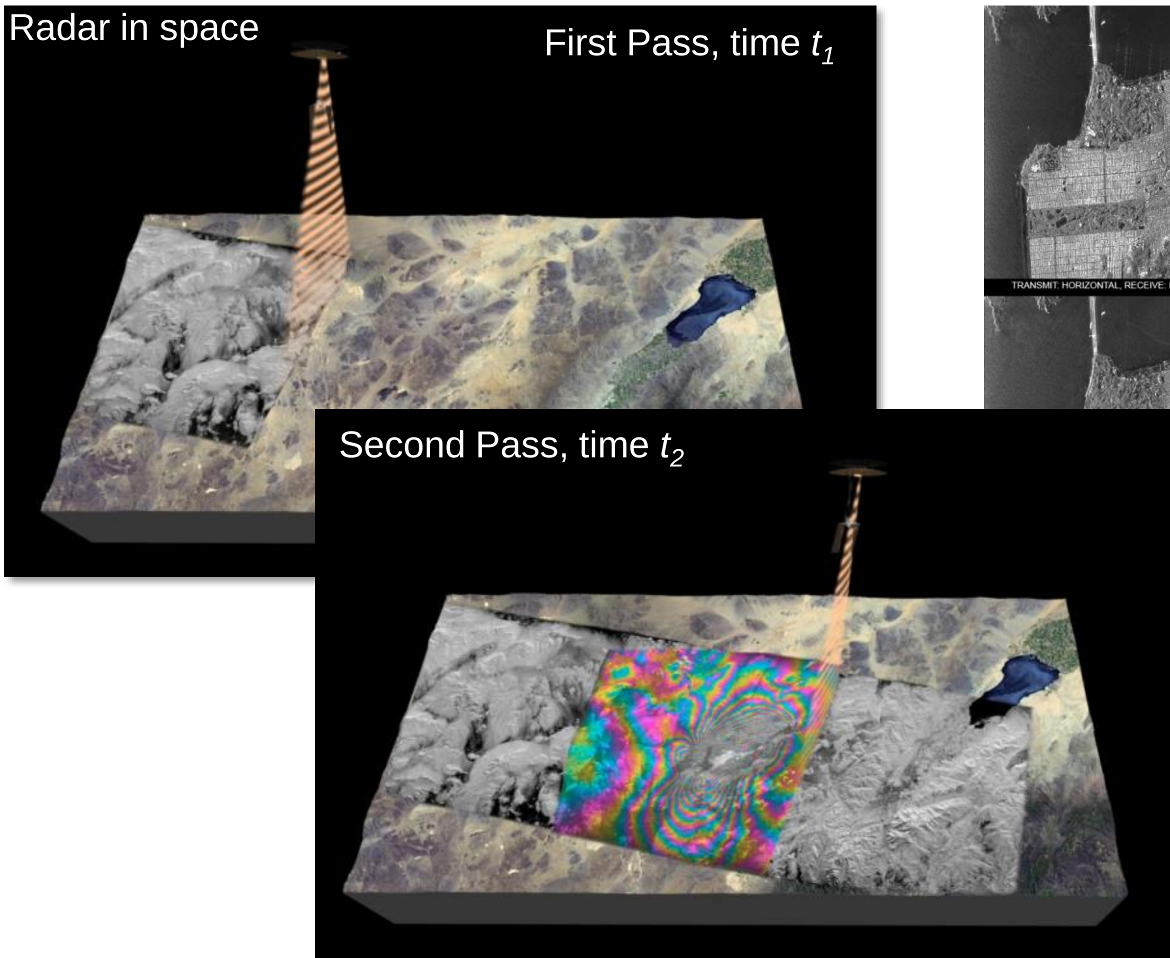
NISAR Science Observing/Operations Modes Blanket Land and Ice Coverage Every 12 Days

- Observation strategy employs a subset of possible modes

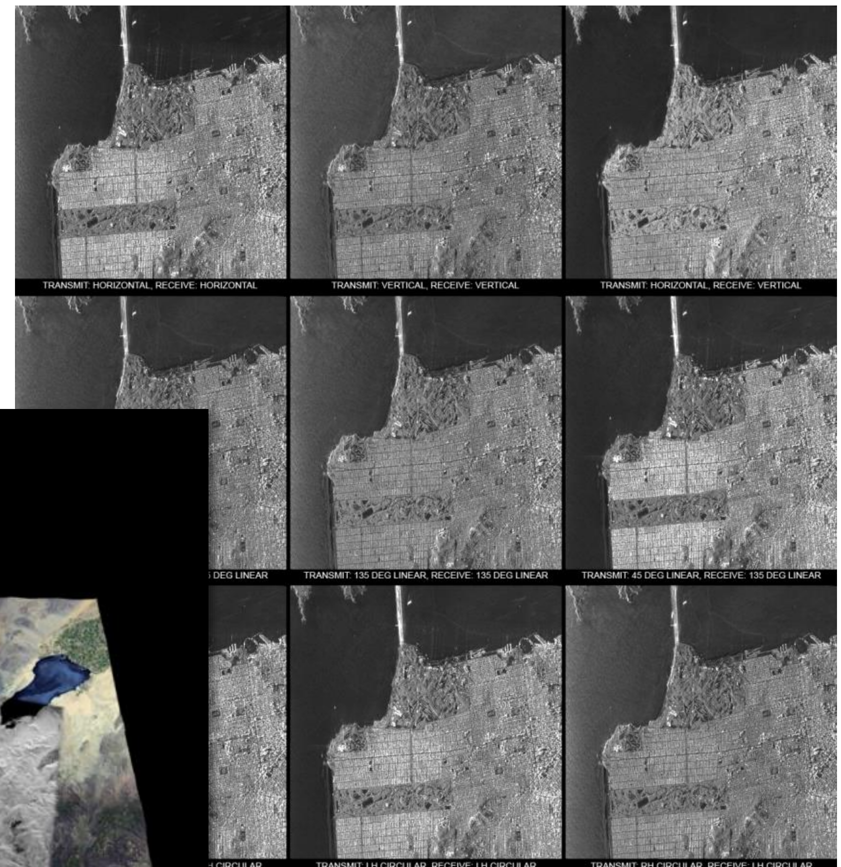
Observation Strategy	L-band		S-band		Culling Approach	
Science Target	**Mode+**	**Resolution**	**Mode**	**Resol.**	Sampling	Desc Asc
Background Land	DP HH/HV	12 m x 8 m			cull by lat	
Land Ice	SP HH	3 m x 8 m			cull by lat	
Sea Ice Dynamics	SP VV	48 m x 8 m			s = 1 p	
Urban Areas		6 m x 8 m			s = 1 p	
US Agriculture	QP HH/HV VV/VH				s = 1 p	
Himalayas			CP RH/RV		s = 1 p	
India Agriculture					s = 1 p	
India Coastal Ocean			DP HH/HV or VV/VH		s = 1 p	
Sea Ice Types	DP VV/VH				s = 3 p	

NISAR Measurements
to Achieve Science Objectives

Repeat Pass Interferometry

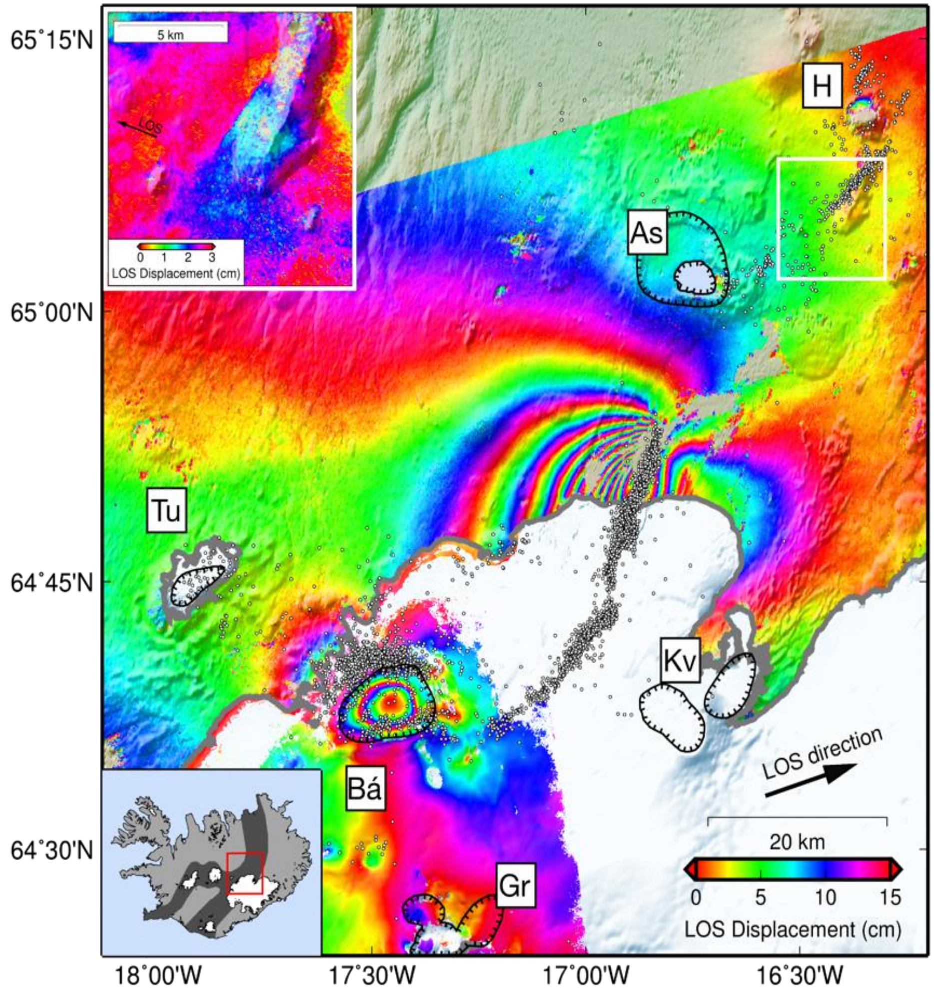


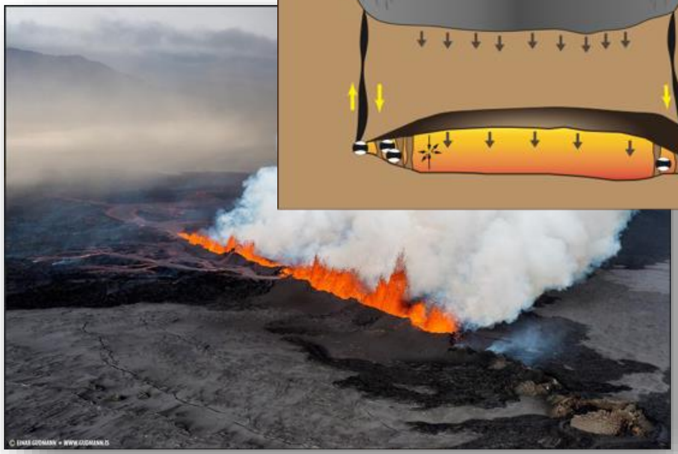
Polarimetric Diversity

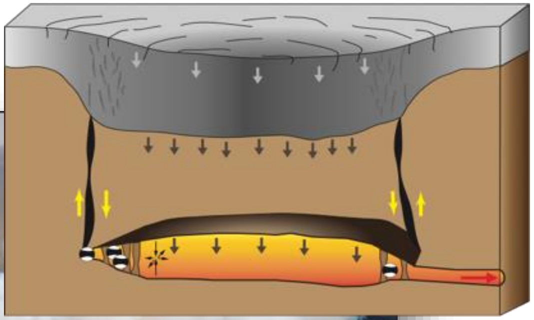


Collapse of Bárdabunga Caldera (Iceland) & associated plate boundary rifting

Fast Sampling (COSMO-SkyMed 1-day) fills in Radarsat 2 24-day pairs

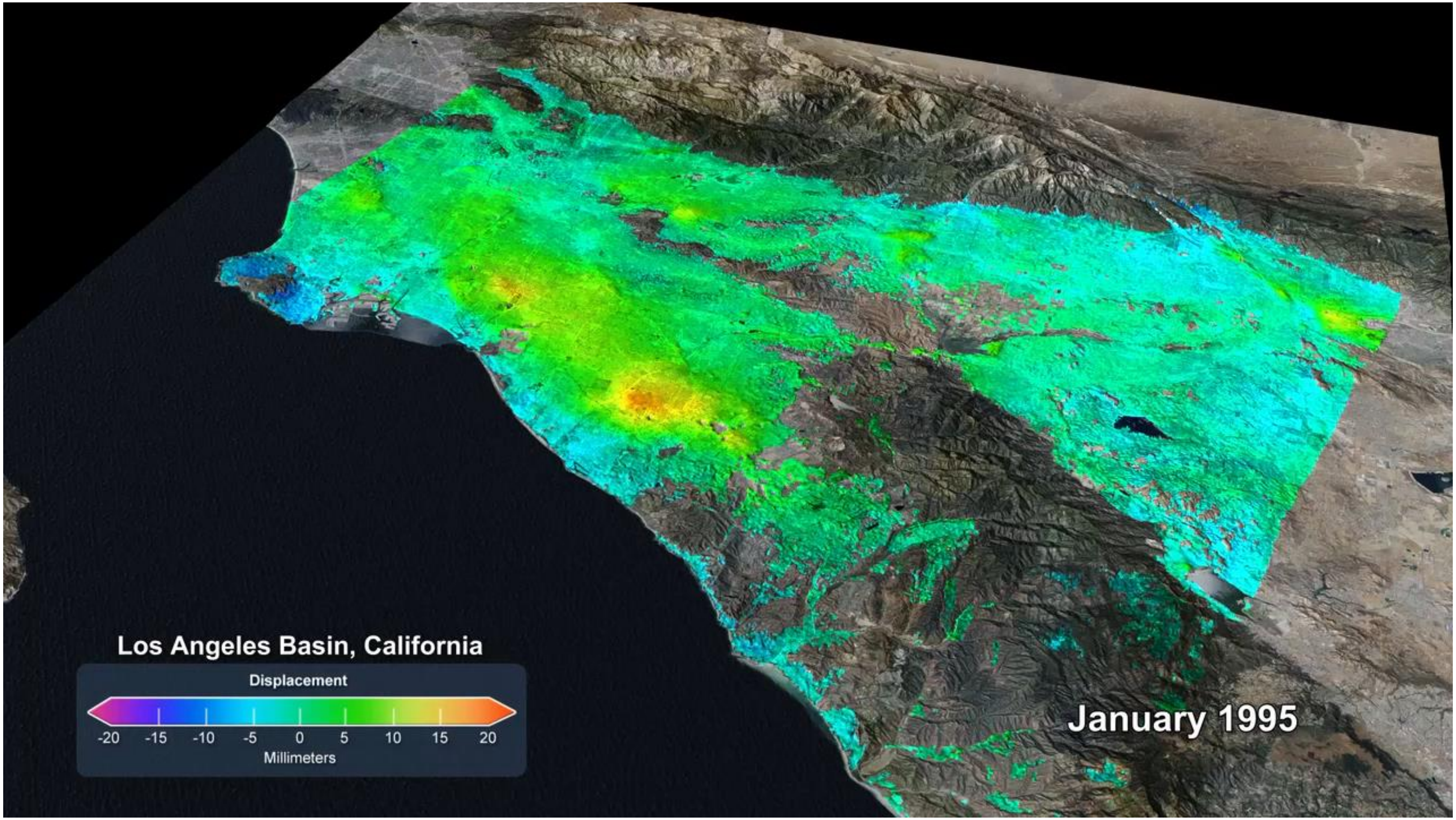




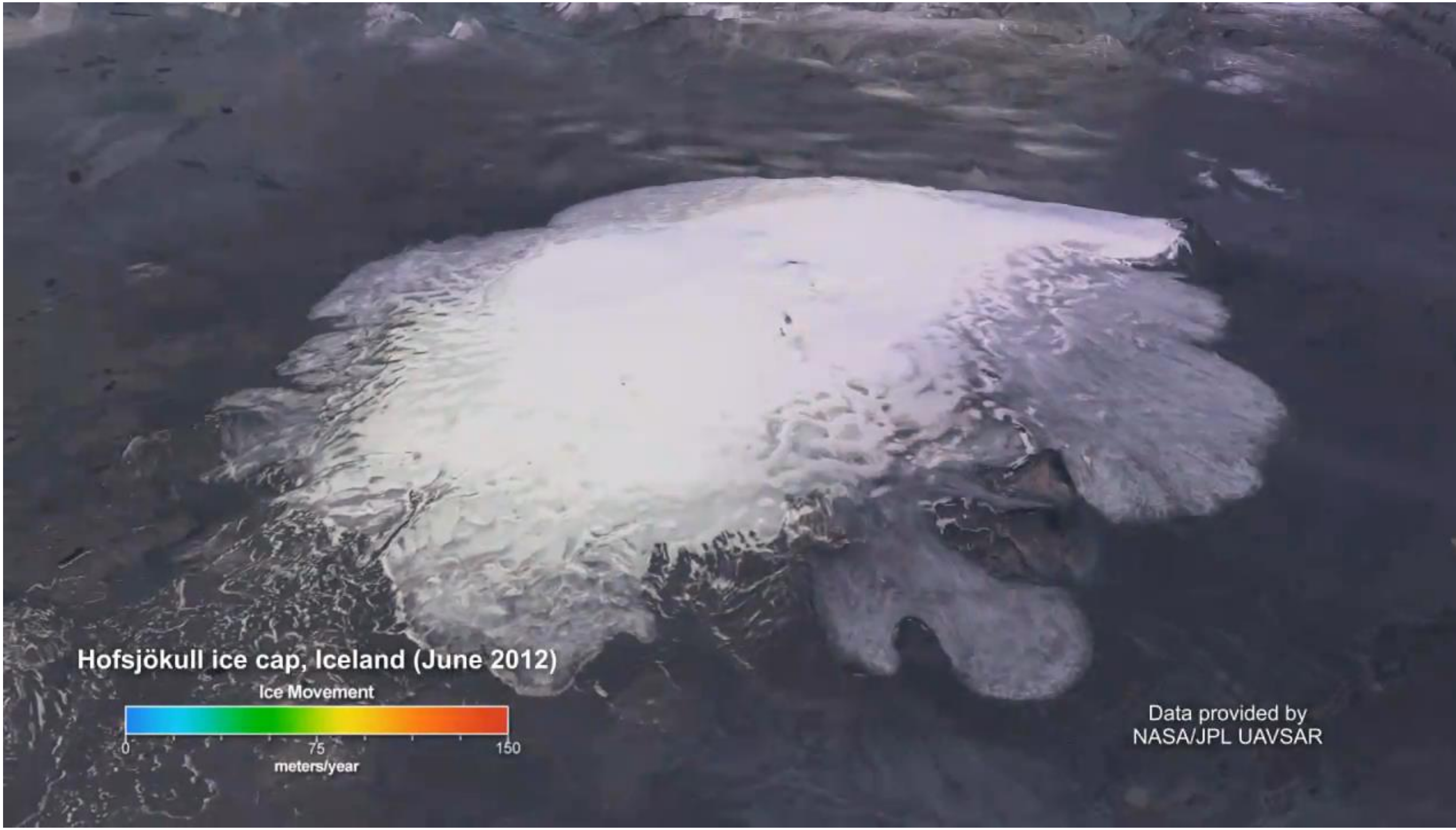


Riel et al., *Geophys. J. Int.*, 2015

Measuring Aquifer Usage In Los Angeles



Science by Capturing the Dynamics of Earth



Benefits of Dual Frequency Radar

As demonstrated by the NASA Shuttle Imaging Radar-C in 1994:

- Use of S-band in polar regions could reduce the impact of the ionosphere, since the S-band signal will be 5 times less sensitive than L-band to ionospheric perturbations.
- Use of L-band and S-band jointly would
  - allow an improved estimate of the ionosphere using dual-band mitigation techniques.
  - extend the range of sensitivity for biomass estimation and surface deformation, and aid in estimating soil moisture.
  - improve classification of natural surfaces
  - Improve the utility of interferometry for change detection, and change classification
- S-band instrument has greater coverage capacity than scheduled
  - Mission trades will determine best balance between L and S-band observations

Benefits of both US-contributed L-band SAR and India-contributed S-band SAR

- *Global* L-band and *globally-distributed but targeted* S-band data with unprecedented spatial and temporal sampling will drive new directions in science and applications, including high-resolution soil-moisture and crop assessments

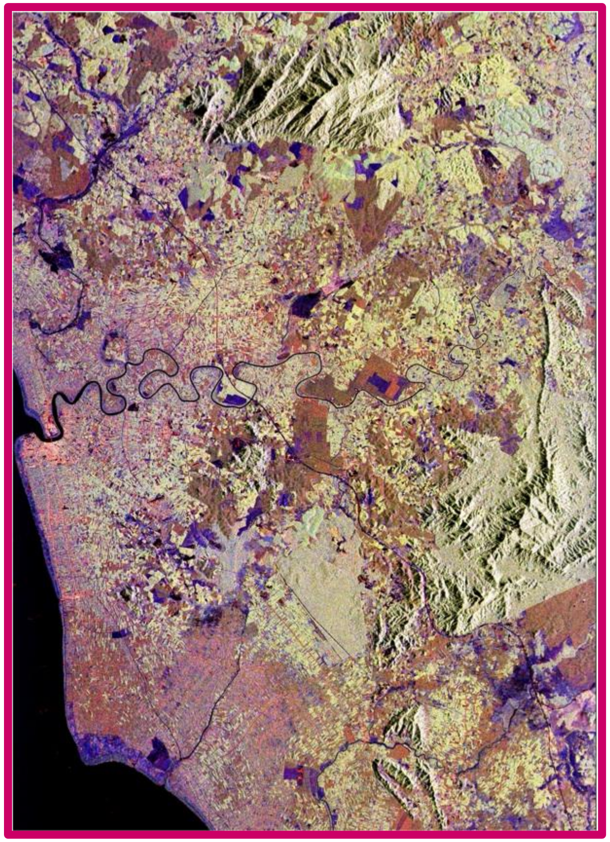
Wheat Fields,

Dnieper River, Ukraine

Red: LHH
Green: LHV
Blue: CHV

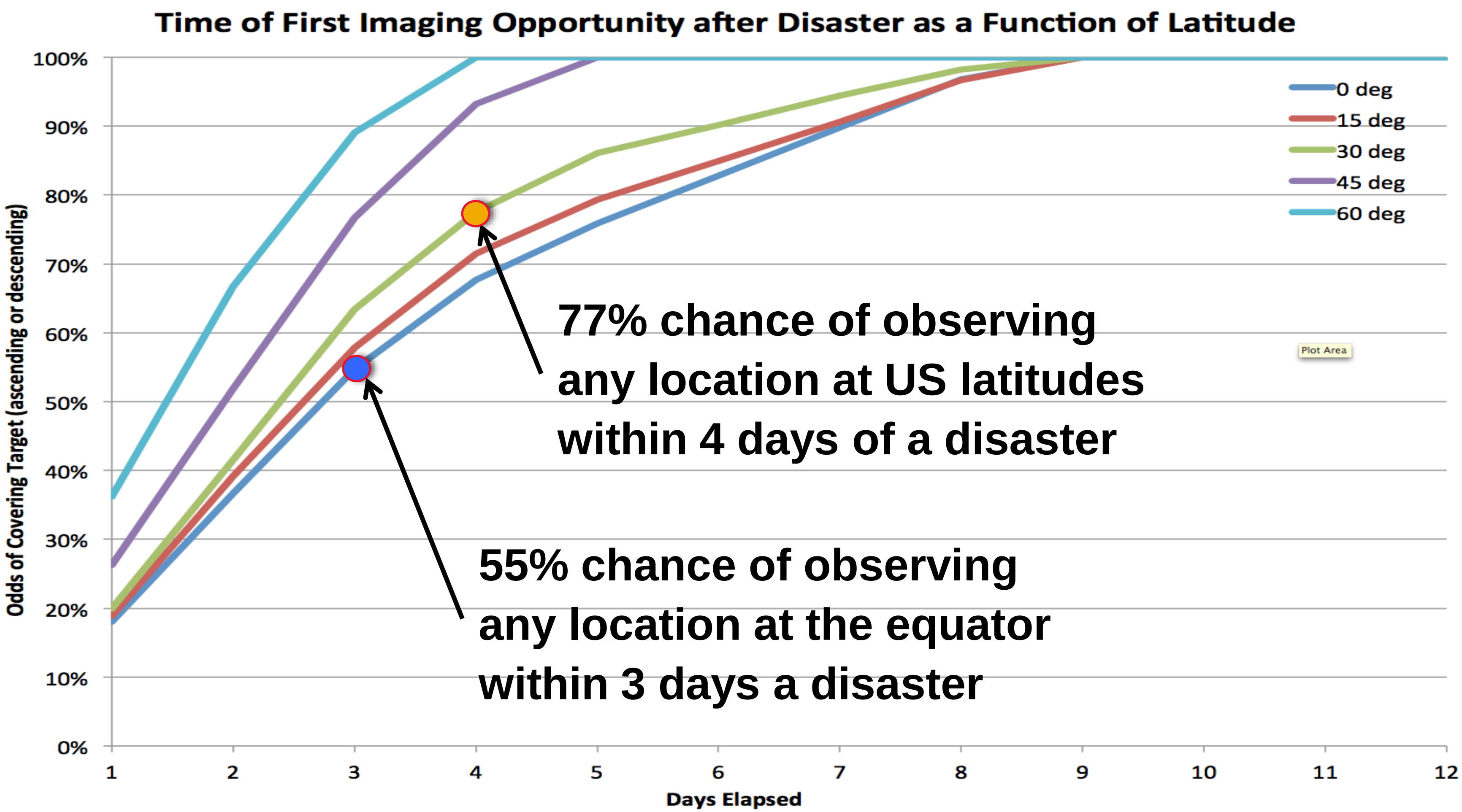
Rubber, banana, and oil palm trees,

Muar, Malaysia



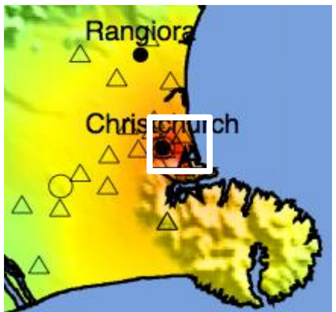
Examples of dual-frequency measurements from SIR-C/X-SAR

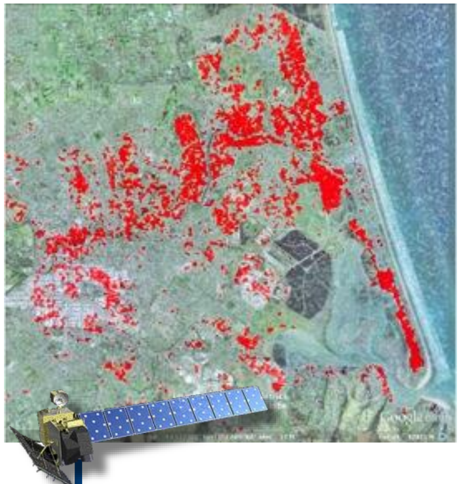
Rapid Response Time-to-Image for 12-day repeat SAR

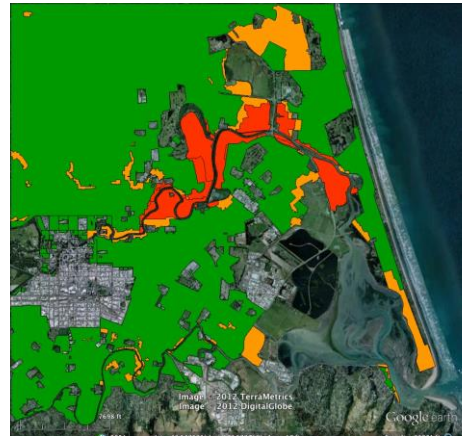


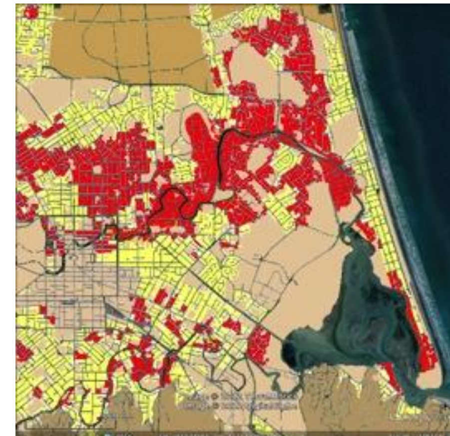
Application to Improve Disaster Response

Damage Proxy Map from radar data









Shakemap released by USGS NEIC

Radar data acquired by ALOS satellite

Official damage map released based on ground observations

Official damage map updated based on ground observations

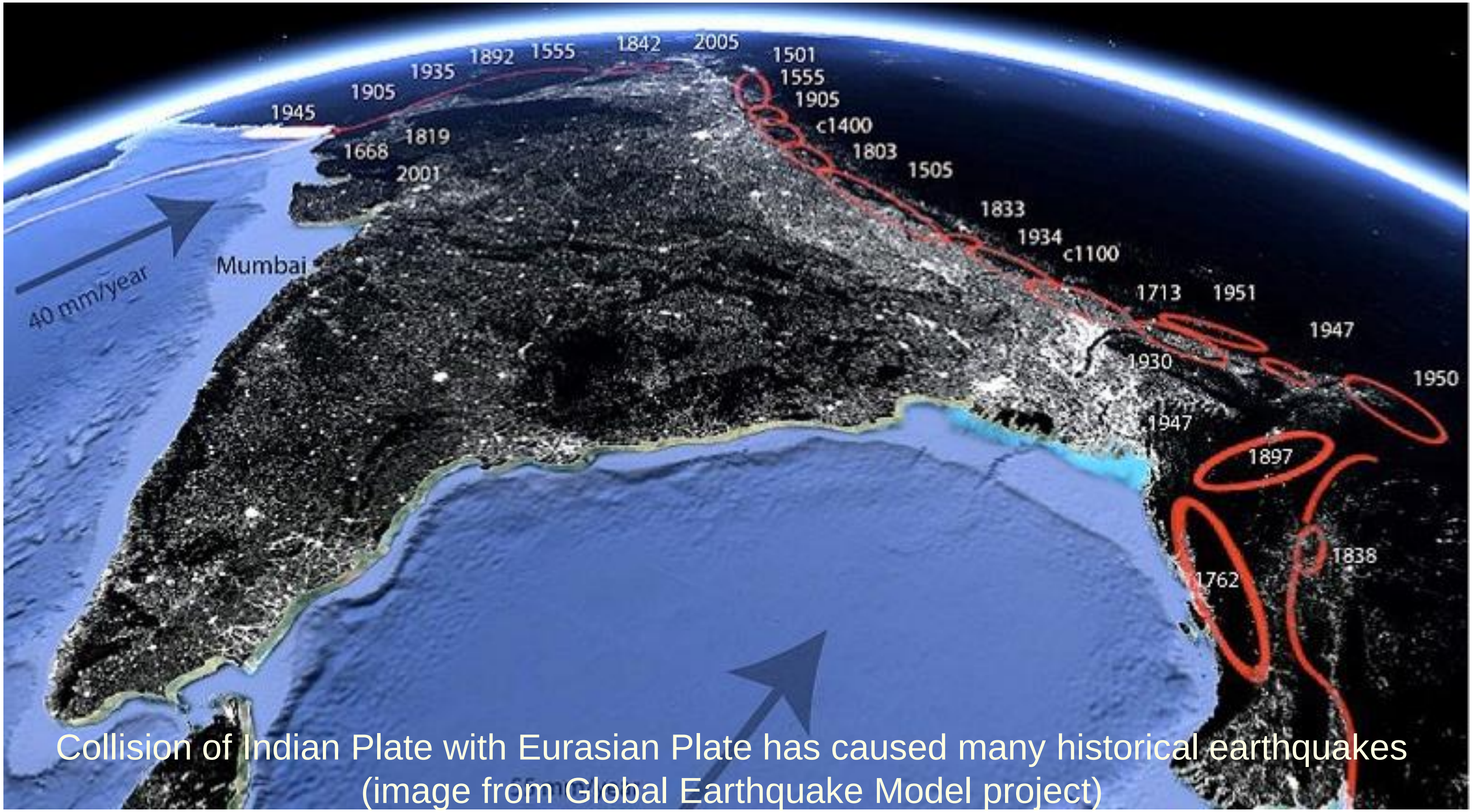
2011 | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct

M6.3 Christchurch Earthquake

185 people killed   > 1000 buildings destroyed   Over US $30 billion damage

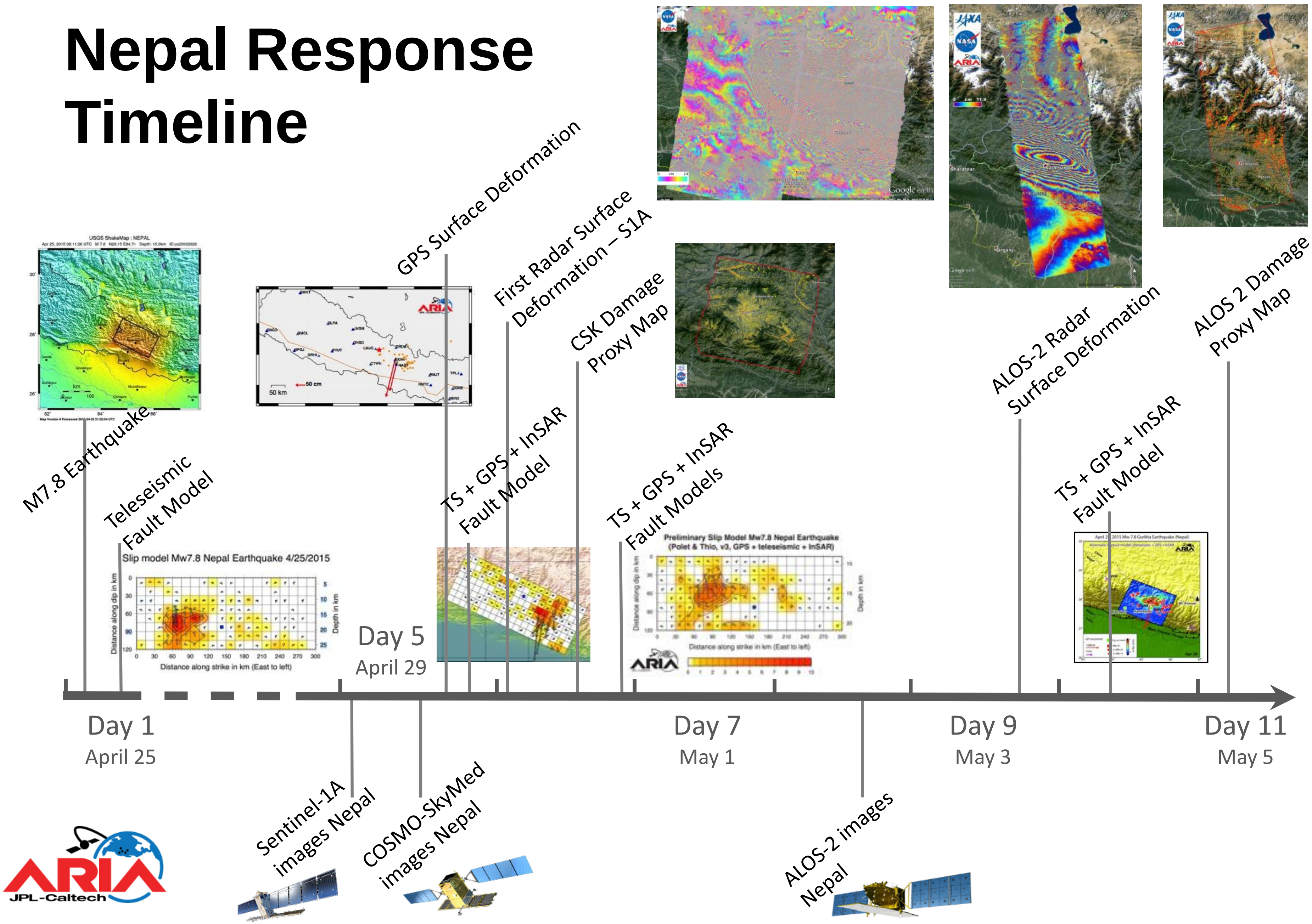
Sang-Ho Yun, JPL

2016 M7.8 Gorkha, Nepal Earthquake



Collision of Indian Plate with Eurasian Plate has caused many historical earthquakes (image from Global Earthquake Model project)

Nepal Response Timeline



NISAR Session SS-01 11:00-12:30

- Please come to the NISAR Session to hear more on mission, science, instruments, and products

- Questions?

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Click on “**Home Tab**,” then click on the downward arrow next to the “**New Slide**” icon located on the left corner of the menu bar.

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